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Status of Atlantic salmon at Highlands River, Bay St. George, SFA 13, Newfoundland, 1999

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Abstract

The status of Atlantic salmon in Highlands River, 1999 was determined from the number of salmon counted through a fish counting fence located on the main stem of the river just above head of tide. Biological characteristics data were collected from kelt and updated summaries for past years are provided. Adult returns in 1999 were 146 small salmon and 82 large salmon. This represented an increase of 52% for small salmon in comparison with 1998 but a 30% decline in numbers of large salmon from the previous year. Marine survival increased on both small and large salmon components, but is still anomalously low given the substantial reductions in directed marine fisheries for Atlantic salmon. The proportion of the conservation requirement achieved for Highlands River in 1999 was 48.8% with the 5th and 95th percentiles of 39.1 to 58.9%. On average for the period of 1993-97, Highlands River has achieved 74.9% of its conservation requirement.

Population estimates of juvenile salmon were made at 5 sites. Collective results suggest higher densities of 0+, 1+ and 2+ parr over 1998, but overall there appears to be little correspondence among juvenile life stage salmon densities. Smolt production should show an additional increase in 2000, but in the absence of substantial improvements in marine survival, the conservation spawning requirement for Highlands River is not expected to be attained in 2000.

Résumé

L'état du saumon de l'Atlantique de Highlands River en 1999 a été déterminé à partir du nombre de saumons dénombrés à une barrière de comptage située sur le cours principal de la rivière, juste en amont de la ligne de la marée. Des données biologiques ont été recueillies pour les charognards et des résumés à jour des données antérieures sont présentés. Les remontées d'adultes comptaient 146 petits et 82 grands saumons en 1999. Cela représente un accroissement de 52% pour les petits saumons par rapport à 1998, mais les remontées des grands saumons ont diminué de 30% par rapport à l'année précédente. La survie en mer a augmenté pour les petits et grands saumons, mais elle est encore anormalement faible compte tenu des réductions considérables des pêches marines dirigées du saumon de l'Atlantique. La proportion des besoins de conservation atteinte pour Highlands River en 1999 s'est élevée à 48,8%, les 5^{e} et 95^{e} percentiles se situant entre 39,1 et 58, 9%. En moyenne, les besoins de conservation de Highlands River ont été atteints à 74,9% pour la période de 1993-1997.

La population des saumons juvéniles a été estimée en cinq endroits. L'ensemble des résultats suggère, des densités de 0+, 1+ et 2+ plus élevées qu'en 1998, mais en général il ressort qu'il y existe une faible correspondance entre les densités des jeunes saumons de mêmes stades. La production des saumoneaux devrait s'accroître d'avantage en 2000, mais en l'absence d'une amélioration appréciable de la survie en mer, on nc s'attend pas à ce que les besoins en conservation des géniteurs de Highlands River soient atteints en 2000.

Introduction

The Highlands River is a fourth order system located on the south west coast of Newfoundland (48° 11' 38'' N, 58° 53' 40" W), in Salmon Fishing Area (SFA) 13 (Fig. 1). The river drains westerly into Bay St. George from the southern part of the Long Range Mountains, with an average gradient of about 1.2%, over an axial length of 29.0 km. Area of the drainage basin is 183.1 km^2. The river has long been noted for a fall run of very large salmon, and in the past at least, for good trout fishing (Palmer 1928). Owing to the decline of angling success at the time, especially of the large salmon component, the river was closed to angling in 1978, and has remained so (Chadwick et al. 1978; Porter and Chadwick 1983; Gibson et al. 1987). In the 10-year period prior to the closure of the sport fishery (1968 - 77), angled catch of small salmon ranged from 16 to 105 fish per year ($\bar{x}$ = 39.0 $year^{-1}$) while large salmon catch varied from 4 to 25 ($\bar{x}$ = 11.8 $year^{-1}$). Prior to 1968, annual angled catches of 50 to 97 large salmon were reported (Moores et al. 1978).

Adult spawning escapement and smolt yields have been obtained from a fish counting fence that operated from 1980 to 1982, and again from 1993 to 1999. Adult returns have ranged from 96 to 398 small salmon ($\bar{x}$ = 160) and from 29 to 157 large salmon ($\bar{x}$ = 98). The highest runs occurred in 1997 (Reddin and Whalen 1998) while the lowest returns, over the entire period of record, were in 1980. Smolt production has varied from 5922 to 15839 ($\bar{x}$ = 11061) with the fewest smolts occurring in 1997 and 1998. The low smolt runs were believed to have been the result of a severe flood that affected the river in February, 1996 (Reddin and Whalen 1998), which was the most extreme event recorded since 1982 (Dempson and Clarke 1999). Juvenile salmon population estimates were made in 1980 and 1981, and from 1993 to 1999. Surveys carried out from 1997 - 1999 were based on a reduced subset (N = 5) of stations and thus were not as thorough as in previous years. Based on past assessments (Gibson et al. 1994, 1996; Reddin and Whalen 1998), it was determined that less than 40% of the conservation requirement was achieved at Highlands River from 1980 to 1982. With the closure of the Newfoundland commercial salmon fishery in 1992, the percentage of the conservation requirement attained has averaged about 72.2% (1993 - 1998) but in only one year, 1997, has the actual conservation spawning requirement been obtained.

This paper summarizes smolt production and returns of adult Atlantic salmon to Highlands River in 1999 along with results of juvenile salmon population estimates from electrofishing surveys. In addition, information on environmental characteristics are provided, biological characteristic data for Atlantic salmon updated, and information on recoveries of tagged kelt are summarized. Owing to the impact of the 1996 flood event on subsequent smolt production, we also provide an update of the hydrological conditions at Highlands River for the period 1982 – 1999 (1999 data preliminary).

Methods

1. Environmental conditions

Water temperatures were obtained from a continuous recording Hugrun thermograph set 1 m from the surface at the fish counting fence site located in the lower river and operated from November 16, 1998 to November 5, 1999; however, only data from April 10, 1999 are illustrated in this report. Discharge information for the period 1982 - 1999 was obtained from Environment Canada records for the gauging station situated where the Trans Canada Highway crosses over the major stem of Highlands River ('River Brook'; Fig. 1). The drainage area above the water gauge is 72 km^2, which represents 39% of the reported total drainage area for the entire Highlands River watershed.

2. Biological characteristics

Biological characteristic information on smolts, including fork length to the nearest millimeter, whole weight to the nearest one hundredth of a gram, sex, and scales were derived from samples captured at the fish counting fence. Samples of adult salmon, obtained from kelt emigrating in the spring, provided information on fork length to the nearest centimeter, scales and a visual inspection (external) to determine sex. Some returning adult salmon were also sampled for fork length to the nearest centimeter, scales and sex (external). Additional information on fork lengths (to the nearest 5 centimeters) has been obtained over the years from visually estimating lengths of returning adults when they were in the counting fence trap where a fish measuring stick was placed along side of salmon. These data are provided for reference but we caution that except for 1980 and 1981, the distributions should not be interpreted as reflecting the overall length distribution of the run in each year. Smolt scales from 1995 have been reanalyzed for this assessment, as recommended last year.

3. Smolt monitoring

Standard conduit smolt and adult counting fences were installed according to the description in Anderson and McDonald (1978). The smolt fence operated from April 29 until June 23, 1999 (Table 1).

4. Kelt tagging

As in 1998, a number of kelt counted at the downstream fence in 1999 were tagged and released with either individually numbered temperature recording archival tags (N = 29) or Carlin tags (N = 37).

5. Juvenile salmon population estimates

Population estimates were conducted during July at the five sites sampled in 1999. Stations were chosen to reflect different stretches and habitat types in Highlands River. Densities of small salmonids were estimated by the depletion method in riffles and the flat with the use of an electrofisher. Four (4) sweeps done at each of the sites electrofishing in an upstream direction from the lower end of the study area. If no fish were caught in the first sweep, no further sweeps were made. Habitat variables were measured at each site according to the method described in Gibson et al. (1993).

6. Adult salmon returns, sea survival and egg deposition

The adult fence was installed on June 9 to catch upstream migrating adult salmon. The trap and fence were removed for the season on October 31, 1999 (Table 1). All fish were counted, and sizes of adult upstream migrating salmon were estimated. All fish were released alive. Since the river is closed to angling, no adult fish were killed for more detailed sampling.

The adult fence was fished with every second conduit removed; therefore, smaller fish counted migrating upstream could be an underestimate since some could pass through the fence and not be counted at the trap. The trap was checked and fish released on a regular 4-hour basis from 0800 hrs to 2000 hrs (during the peak of the runs and during high water levels the trap was checked more frequently). The adult salmon counted were sized in two categories; small salmon were those less than 63 cm in fork length while large salmon were fish 63 cm or greater.

Sea survival was determined from the number of small salmon returning in year i+1 or the number large salmon in year i+2 relative to the number of smolts that emigrated in year i. Adult salmon returning to Highlands River are characterized by several life-history types including virgin one sea-winter (1SW), two sea-winter (2SW), three sea-winter (3SW) and previous spawners of each of these life histories. Thus, an estimate of survival to the 2SW life history stage is also provided.

Because Highlands River is closed to angling, total river returns or spawning escapement (SE) were simply the numbers of fish enumerated at the fish counting fence. Egg deposition (ED) was calculated separately for salmon < 63 cm (small salmon) and salmon $\geq$ 63 cm (large salmon) and then totaled:

$$ED = SE \times PF \times F$$

where, PF = proportion of females
F = fecundity at size.

For this assessment, egg deposition was been calculated as in the previous years assessment (Dempson and Clarke 1999) using the average biological characteristic information (proportion females and mean lengths) obtained from samples of kelts, separately for small and large salmon, for two time periods 1980 - 1982, and 1993 – 1998. Mean values were used because the numbers of samples obtained in any specific year are generally limited:

Size		1980 - 82	1994 - 98
Small	% female (N)	55.4 (74)	46.1 (191)
	mean length, cm (N)	52.0 (41)	53.1 (88)
Large	% female (N)	75.0 (80)	69.5 (203)
	mean length, cm (N)	85.2 (60)	81.6 (141)

Fecundity estimates were taken from Randall (1989):

Small salmon: Ln fecundity = -4.5636 + 3.1718 Ln (FL in cm); and,

Large salmon: Ln fecundity = -1.1862 + 2.3423 Ln (FL in cm).

The above equation for small salmon was originally derived for 1SW Miramichi River fish, while the equation used for large salmon was that derived from a composite of 2SW, 3SW and previous spawners from the Restigouche River.

Conservation egg deposition requirement

The conservation requirement for Highlands River is 1,498,475 eggs. This was derived from:

fluvial habitat	=	6219.26 units @ 240 eggs/unit
lacustrine habitat	=	15.9043 ha @ 368 eggs/ha

(Reddin and Whalen 1998).

Results and Discussion

1. Environmental conditions

Water temperatures - 1999

Mean daily water temperatures were less than 7 °C during the month of April, with average water temperatures reaching 10 °C for the first time on May 7 (Fig. 2). May and June water temperatures averaged 10.8 and 16.7 °C, respectively. Temperatures continued to increase reaching a mean daily temperature of 20 °C for the first time on July 3 (Fig. 2). There were 16 days in 1999 when the mean daily water temperature was 20 °C or warmer. Mean daily water temperature reached a peak value on July 18 at 22.5 °C. Over the entire summer, there were 40 days when maximum temperatures ≥ 22 °C were reached and 8 days when maximum temperatures ≥ 25 °C were obtained. The latter occurred between the dates July 17 to August 4. Mean daily water temperatures declined sharply in late September with mean daily water temperatures remaining below 10 °C from October 8 onward.

Water level and Discharge – 1999

Mean daily water levels recorded at the fish counting fence trap at Highlands River ranged from about 20 to 79 cm (Fig. 2). Water levels were moderately high in April and May ($\bar{x}$ April = 45.6 cm; May = 43.2 cm) with the June and July water levels low ($\bar{x}$ June = 25.0 cm; July = 22.7 cm), and generally high during much of October ($\bar{x}$ October = 44.3 cm), with the highest daily average value recorded October 15 (78.3 cm). There were 24 days when the maximum water level recorded was ≥ 50 cm, and 18 days when the mean daily water level exceeded this value.

Preliminary discharge information, obtained from the Environment Canada station on Highlands River, indicated moderate water levels during the peak smolt run (May 10 - June 1; $\bar{x}$ = 4.2 m^3/sec; range = 1.2 - 10.9 m^3/sec) with moderately low water levels throughout much of the adult migration (Fig. 3). On only 16 occasions did discharge values exceed 5 m^3/sec during the adult salmon run (from June 9- October 31). The peak mean daily discharge during the adult run was recorded on October 15 (15.2 m^3/sec). Information for the months of January and February, 1999, were incomplete. Past years are included for comparison in Fig. 3.

2. Biological characteristics

Table 2 summarizes the updated biological characteristic data of Atlantic salmon from Highlands River. Length and weight of smolts sampled in 1999 were similar to the average from all years ($\bar{x}$ = 12.9 cm and 20.4 g). Adult salmon have been partitioned into small and large categories with small salmon averaging 54.2 cm and large salmon 81.3 cm. All adult salmon data reported were obtained from sampling kelts leaving the river during the spring of the year. The summary includes repeat spawners.

River age distribution of smolts is provided in Table 3. Smolts are predominately 3+ (71.7%) but there is considerable variation among years ranging from 48.0% river age 3 smolts in 1999 to 90.5% in 1998 (Table 3). Note data for 1995 have been updated in this report and differ from that presented in Dempson and Clarke (1999). The estimated contribution of 2+ smolts in 1999 (48%) was the highest recorded and appears anomalous by comparison with previous information. In light of the 1996 extreme flood event at Highlands River, it is tempting to speculate as to whether this is, indeed, evidence of a density dependent response, or is disproportionate owing to the depressed contribution of river age 3+ smolts in 1999. Alternatively, given the variability in smolt ages over the past two years, and corrections required for the 1995 data, smolt age information from 1999 should be reanalyzed as was done for the 1995 data.

Maximum, minimum and mean smolt lengths, by age class, are illustrated in Figure 4. Mean length of age 2+ smolts in 1999 was the highest over the past 7 years (back to 1993), but was smaller than average sizes estimated in 1980 - 1982. Mean size of age 3+ smolts has similarly increased over the past seven years (Fig. 4), and while the mean in 1999 is the highest recorded, it is only marginally different from 1980 and 1998 smolt lengths.

River age distributions of small and large adult salmon are summarized in Table 4. Small salmon are similarly characterized with a river age of 3+ years (72.6%) with 10% of the samples over all years having a river age of 2+ years. In contrast, 81% of the large salmon sampled had a river age of 3+ years while 16.6% smoltified as 2-year old smolts. As shown by O'Connell and Ash (1993) smaller and slower growing smolts in fluvial systems are often characterized by multi-sea winter large salmon. Assuming that age interpretation of 1999 smolts in correct, then there could be a greater proportion of 2SW salmon returning in 2001.

Small salmon at Highlands River are predominantly 1SW fish (96.5%; N_{small} = 318) (Table 5). In contrast, of 331 large salmon kelt that have been sampled, 61.0% were maiden 2SW salmon while 29.9% were previous spawners (Table 5). Twelve (3.6%) virgin 3SW salmon have been sampled at Highlands River since 1980. These fish ranged from 87.0 to 105.0 cm in fork length.

Length-frequency distributions of adult salmon obtained from estimated lengths of fish in the fish counting fence trap are shown in Figure 5.

3. Smolt monitoring

Numbers of smolts migrating downstream each year are summarized in Table 6. The smolt run in 1998 (5922) was the lowest recorded. It is believed that low smolt production in 1997 and 1998 was a result of the extreme high water discharge events that affected Highlands River in February, 1996. The 1999 smolt run increased by 63% from 1998, and to date, appears to be characterized by a high proportion of river age 2+ fish. Two-year old smolts sampled in 1999 would have originated from salmon that spawned in the fall of 1996 and would not have been impacted by the February 1996 flood. Assuming these data are correct, then the February 1996 extreme flood event appears to have impacted the eggs that were in the gravel at that time, which would be the 0+ fry in 1996, along with the river age 1+ and 2+ parr. Alternatively, had the contribution of river age 3+ smolts in 1999 been similar to most other years, averaging around 70% or so, then this could have indicated that the 1996 flood event impacted the 1+ and 2+ parr in the river in 1996 more so than eggs that were still in the gravel redds.

Smolt run timing at Highlands River is illustrated in Figure 6. For the period 1993 - 1998, the median date of the smolt run was May 31, approximately two weeks later than the smolt run at Conne River (May 18). In 1999, the median date of the smolt run was May 22, the earliest to date.

In addition to Atlantic salmon parr (N= 295), smolts, and kelt (N = 126), both resident (N = 91) and sea-run (N = 473) brook trout, smelt and eels were enumerated passing downstream in 1999.

4. Kelt tagging

Kelts upon which archival tags were applied in the spring of 1999 (N = 29) averaged 65.8 cm in fork length (range: 51.0 - 96.0 cm). Seven (7) of these fish were subsequently recovered (Table 7). Six (6) of the salmon returned to Highlands River while one (1) was captured in the salmon angling fishery in Humber River (Drill Hole), 54 days after it was released. Carlin tagged salmon (N = 37) averaged 59.7 cm in fork length (range: 46.0 - 96.0 cm). Of these fish, four (4) were subsequently recovered as they returned to Highlands River (Table 7). In contrast with kelt tagging in 1998 where several salmon were captured in either Quebec North Shore commercial salmon fisheries or in the Newfoundland sentinel cod fishing traps (Table 7), to date none of the 1999 kelt tags have been reported caught in any marine fisheries.

With respect to kelts tagged in either 1998 and 1999 that subsequently returned to the Highlands River in the same year of release, we note the following in terms of the number of days fish were at large prior to their recapture back at the fish counting facility:

Year	No. of Fish	Number of Days Free		
		Mean	Min	Max
1998	6	95.5	81	112
1999	10	82.5	53	103

5. Juvenile salmon population estimates

The lower riffle station in River Brook (Station 20) showed exceptional increases in density of underyearlings (age 0+) in two of the years following the moratorium (1994 - 1995) compared with previous samples obtained in 1980 and 1981. Densities fell dramatically in 1996. While low densities may have been expected in 1996 following the February 1996 flood event, densities remained low until 1999 (Fig. 7).

Density of age 1+ parr in 1996 did not mimic the decline in 0+ fry observed as the density was moderately high. Densities have increased over the past two years (Fig. 7).

Electrofishing results from other stations survey are illustrated in Figures 8 - 11. While densities of underyearling (0+) fry decreased from 1995 to 1996 at all sites surveyed, results from subsequent years have been quite variable with some stations showing low abundances continuing for several more years (e.g. Station 20) to substantial increases in 1997 (e.g. Station 10). Densities of 1+ and 2+ parr have been variable.

Figure 12 illustrates juvenile salmon densities by age class where results from four of the electrofishing stations have been pooled (Stations 2, 9, 10, and 20; Station 50 was omitted as it was not surveyed in 1997). Pooled results show that 0+ fry densities were low in 1996, but had been falling since 1993. Collective information for age 1+ parr did not indicate an appreciable decline in 1996 coincident with the February 1996 flood event, but densities appear to have increased over the past several years. Age 2+ parr densities are irregular (Fig. 12).

Although data are sparse, the following report correlations among various age classes or life stages:

Group	N	r^2	Significance
Eggs deposited to 0+ fry	6	0.13	N.S.
0+ fry to 1+ parr	6	0.35	N.S.
1+ parr to 2+ parr	6	0.13	N.S.
2+ parr to 3+ smolts	6	0.11	N.S.
1+ parr to 3+ smolts	5	0.97	$P < 0.01$

Interestingly, 1+ parr were correlated with subsequent 3+ smolt, based on 5 sampling points. Otherwise, there appears to be no correspondence among juvenile life stage densities.

Erkinaro and Gibson (1997) have shown that in at least one Newfoundland river system, juvenile salmon can undergo high rates of instream migration and thus poor site fidelity in fluvial habitats. Thus frequent habitat shifts by juvenile salmon can influence the reliability and interpretation of resulting densities obtained from electrofishing surveys. Considerable bias in abundance estimates may also result when surveys are carried out at a small number of sampling sites (Erkinaro and Gibson 1997). An additional confounding problem at Highlands River is related to high variability in stream discharge. Indeed periodic high discharge events have rendered some traditional electrofishing stations unusable while altering the habitat characteristics of others making comparisons among years for fixed stations problematic. The periodic high or extreme discharge events at Highlands River may contribute to this system being somewhat unstable in regards to the production of salmon. Recall that Highlands River has been closed to angling since 1978, and the commercial salmon fishery has been under a moratorium since 1992, yet escapement continues to remain at relatively low levels.

Appendix 1 summarizes the raw numbers of salmon fry and parr caught by sweep at each station for the period 1980 - 1981 and 1993 to 1999.

6. Adult salmon returns, sea survival and egg deposition

Adult salmon returns

There were 146 small salmon and 82 large salmon enumerated at the fish counting fence in 1999 (Table 8, Fig. 13). This represents an increase of 52% in numbers of small salmon but a 30% decline in numbers of large salmon by comparison with 1998. Based upon limited data since 1993, there is no correspondence between numbers of large salmon in year i+ 1 with small salmon in year i ($r^2 = 0.008$). Timing of small and large salmon runs is illustrated in Fig. 6. Despite the early smolt run in 1999, median timing of small salmon returns was the latest recorded.

Sea survival

Marine survival of smolts that migrated in 1998 to small salmon returns in 1999 increased to 2.47% from 1.42% the previous year (Table 9). Estimates of the survival of the 1997 smolt class to large salmon returns and 2SW returns in 1999 were 1.21% and 0.46%, respectively (Table 9). As stated last year, despite major reductions in directed marine fisheries for Atlantic salmon, marine survival rates remain at disturbingly low values.

Egg deposition

Potential egg deposition by small salmon was:

3088 eggs per fish x 146 small salmon x 0.461 proportion females = 207,841 eggs

Potential egg contribution from large salmon was:

9175 eggs per fish x 82 large salmon x 0.695 proportion females = 522,883 eggs

Total potential egg deposition was: 730,724 of which large salmon contributed 71.6%.

Thus 48.8% of the conservation spawning requirement was achieved in 1999 (730,724/1,498,475 = 48.8%), a decrease of 17.2% from that attained in 1998, but 53.4% below 1997 (Table 10). The average conservation requirement obtained over the period 1993 to 1999 is 68.9%, with the conservation spawning requirement achieved in only one year (1997). Table 10 and Figure 13 summarize updated information on egg depositions at Highlands River for all years in which fish counting fences have been operated.

In the above evaluation, only the numbers of small and large salmon returning to Highlands River in 1999 were known with certainty. To account for some of the uncertainty in the potential egg deposition that occurred, we assumed a coefficient of variation of 20% around the fecundity and percentage females of both small and large salmon components and recalculated the estimated egg depositions using 1000 realizations from a uniform distribution, the same procedure as used last year (Dempson and Clarke 1999). Results are illustrated in Figure 14.

Based on this level of variation in fecundity and percentage females, the corresponding 5th and 95th percentiles of the percentage of the conservation requirement met varied from 39.1 to 58.9%.

7. Outlook for 2000

Owing to the low smolt runs in 1997 and 1998, a crude estimate of returns in 1999 was made by applying the range in survival rates from smolts to small salmon (1.42 - 3.21%) and from smolts to large salmon (0.94 - 1.35%) to the 1998 (N = 5922) and 1997 (N = 6776) smolt runs, respectively. This approach indicated that 84 to 190 small salmon could return in 1999 and from 64 to 91 large salmon. Actual returns were 146 small and 82 large.

Applying the same range in survival rates to the 1999 and 1998 smolt runs suggest that returns in 2000 could vary from 137 - 309 small salmon and 56 to 80 large salmon. If survival rates fall within the values previously reported, then the 'worst' and 'best' case scenarios from the above exercise would mean that only 37 to 63% of the conservation requirement could be achieved in 2000.

To achieve 100% of the conservation requirement in 2000, based upon the average egg deposition contribution from small (24.9%) and large salmon (75.1%) respectively over the past 7 years (1993 - 1999), marine survival rates approximating 2.7% for small salmon returns from 1999 smolts (~ 262 small salmon) and 3.0% for large salmon returns from the 1998 smolt class (~ 176 large salmon) would be required. While small salmon survival of this rate has been exceeded in the past (Table 9), the survival to large salmon of 3% has never been achieved at Highlands River during the years that the fish counting fence has been in operation.

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Table 1. Summary of fish counting fence operation dates at Highlands River, SFA 13, Newfoundland.

Year	Smolt counts		Adult salmon counts	
	Start	Finish	Start	Finish
1980	May 7	June 30	May 7	Oct 13
1981	April 27	-	-	Sept 9
1982	May 23	-	-	Sept 29
1993	May 18	June 16	June 18	Sept 28
1994	May 18	June 21	June 22	Oct 13
1995	May 14	June 8	June 12	Oct 25
1996	April 26	June 14	June 14	Oct 22
1997	May 23	July 14	June 20	Nov 2
1998	May 6	June 13	June 14	Oct 26
1999	April 29	June 23	June 9	Oct 31

Table 2. Summary of biological characteristics for Atlantic salmon samples from Highlands River, Newfoundland (SFA 13). Specimens of small and large salmon were obtained from sampling kelts when they were leaving the river in the spring of the year.

Lifestage	Year	Fork length (mm)					Whole weight (g)					River age (y)					Sex Ratio	
		N	Mean	SD	Min	Max	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max	N	% female
Smolt	1980	337	132	12.5	100	173	337	22.0	5.9	8.7	44.4	337	2.80	0.47	2	4	324	66
	1981	261	127	9.8	94	159	248	19.5	4.2	9.3	38.0	261	2.89	0.54	2	5	248	70
	1982	324	131	16.5	83	180	324	21.1	7.2	5.4	48.0	324	2.92	0.51	2	5	282	71
	1983	118	118	15.5	76	160	118	16.9	5.9	4.4	37.1	118	2.92	0.83	2	6	117	66
	1984	164	122	10.7	96	154	164	16.5	4.5	7.9	31.8	164	3.21	0.52	2	4	164	63
	1985	178	129	12.8	102	169	177	20.3	6.1	10.7	54.0	178	3.20	0.51	2	5	178	65
	1986	239	127	12.8	85	171	236	19.3	5.7	5.3	43.7	239	2.87	0.53	1	4	208	67
	1987	137	129	11.5	102	165	137	20.2	5.4	11.3	39.9	137	2.92	0.44	2	4	137	63
	1988	126	137	10.8	108	169	126	23.0	5.3	13.0	41.0	126	3.03	0.31	2	4	68	62
	1989	198	129	13.7	101	167	198	20.4	6.5	10.0	39.7	198	2.56	0.57	2	4	102	56
TOTAL		2082	129	13.6	76	189	2065	20.2	6.1	4.4	54.0	2082	2.91	0.54	1	6	1828	66
Small	1980	34	536	46.6	390	595						34	2.97	0.39	2	4	34	41
	1981	14	552	37.4	490	620						14	2.86	0.36	2	3	14	57
	1982	28	527	33.8	450	600	28	1093	253.8	500	1700	29	3.24	0.51	2	4	26	73
	1984	18	541	45.4	445	600						18	3.17	0.38	3	4	18	28
	1985	8	563	31.1	515	600						8	3.00	0.00	3	3	8	63
	1986	54	529	36.2	400	600						54	3.15	0.49	2	4	54	48
	1987	84	556	46.5	420	625						84	3.07	0.60	2	4	84	39
	1988	27	544	39.5	465	625						27	3.07	0.55	2	4	27	70
	1989	51	539	36.3	460	620						51	2.96	0.56	2	4	8	63
TOTAL		318	542	42.1	390	625	28	1093	253.8	500	1700	318	3.07	0.52	2	4	273	49
Large	1980	26	896	111.6	710	1100						26	2.62	0.50	2	3	26	65
	1981	43	820	87.7	630	1050						43	2.84	0.37	2	3	43	66
	1982	12	845	102.3	650	1100	12	4100	1009.1	2200	6000	12	2.92	0.29	2	3	11	55
	1984	18	782	82.9	645	1000						18	3.06	0.24	3	4	18	56
	1985	31	762	78.9	630	1000						31	2.90	0.40	2	4	31	77
	1986	40	806	90.7	645	1030						40	2.98	0.28	2	4	40	70
	1987	67	811	90.4	635	1120						67	2.90	0.40	2	4	67	70
	1988	27	819	90.0	630	1035						27	2.74	0.45	2	3	27	67
	1989	47	786	99.9	630	1040						47	2.79	0.51	2	4	26	69
TOTAL		331	813	95.7	630	1120	12	4100	1009.1	2200	6000	331	2.86	0.41	2	4	309	71

Table 3. Estimated total numbers of smolts in each age class at Highlands River, Bay St. George, Newfoundland. The percentage in each age class is shown in the lower part of the table. Information has been updated from last year following reanalysis of some some smolt ages.

Year	River age (years) 2	3	4	5	6	Total
1980	3426	11151	451	0	0	15028
1981	3152	11467	1093	127	0	15839
1982	2142	9174	1027	37	0	12380
1993	2027	6940	849	85	85	9986
1994	515	7236	2752	0	0	10503
1995	547	8682	2870	61	0	12160
1996	2440	8965	978	0	0	12383
1997	942	5441	393	0	0	6776
1998	190	5359	373	0	0	5922
1999	4624	4624	386			9634

Year	Percent in each age class 2	3	4	5	6	Number of samples
1980	22.8	74.2	3.0	0	0	337
1981	19.9	72.4	6.9	0.8	0	261
1982	17.3	74.1	8.3	0.3	0	324
1993	20.3	69.5	8.5	0.8	0.8	118
1994	4.9	68.9	26.2	0	0	164
1995	4.5	71.4	23.6	0.6	0	178
1996 *	19.7	72.4	7.9	0	0	239
1997	13.9	80.3	5.8	0	0	137
1998	3.2	90.5	6.3	0	0	126
1999	48.0	48.0	4.0	0	0	198
Total	18.7	71.7	9.3	0.2	-	1767

* One river age 1 smolt reported

Table 4. River age distribution (%) of small and large salmon sampled as kelt leaving Highlands River, Bay St. George, Newfoundland.

Small salmon

Year	Percent in each age class 2	3	4	5	Number of samples
1980	8.8	85.3	5.9	0	34
1981	14.3	85.7	0	0	14
1982	3.6	67.9	28.6	0	28
1993	-	-	-	-	-
1994	0	83.3	16.7	0	18
1995	0	100.0	0	0	8
1996	5.6	74.1	20.4	0	54
1997	14.3	64.3	21.4	0	84
1998	11.1	70.4	18.5	0	27
1999	17.7	68.6	13.7		
Total	10.4	72.6	17.0	0	318

Large salmon

Year	Percent in each age class 2	3	4	5	Number of samples
1980	38.5	61.5	0	0	26
1981	16.3	83.7	0	0	43
1982	8.3	91.7	0	0	12
1993	-	-	-	-	-
1994	0	94.4	5.6	0	18
1995	13	83.9	3.2	0	31
1996	5.0	92.5	2.5	0	40
1997	13.8	82.8	3.5	0	87
1998	25.9	74.1	0	0	27
1999	25.5	70.2	4.3	0	47
Total	16.6	81.0	2.4	0	331

Table 5. Sea age distribution of small and large salmon sampled as outmigrating kelt at Highlands River, Newfoundland, where 1SW, 2SW and 3SW refer to virgin sea ages.

	Small salmon (Fork length < 63 cm)				Large salmon (Fork length >= 63 cm)				
Year	Number	1SW	2SW	PS	Number	1SW	2SW	3SW	PS *
1980	34	34			26		13	5	8
1981	14	14			43	2	37	2	2
1982	28	28			12	1	10		1
1994	18	18			18		14		4
1995	8	8			31	5	24	1	1
1996	54	53	1		40		24		16
1997	84	77	1	6	87	1	47	3	36
1998	27	27			27	2	15	1	9
1999	51	48		3	47	7	18		22
Total	318	307	2	9	331	18	202	12	99

* Of the 99 previous spawning large salmon sampled, 77 (77.8%) had a virgin sea age of 2, 20 (20.2%) had a virgin sea age of 1, while two (2.0%) had a virgin sea age of 3.

Table 6. Numbers of downstream migrating fish enumerated at the Highlands River fish counting fence.

	Numbers of fish migrating downstream							
	Atlantic salmon			Brook trout				
Year	Parr	Smolt	Kelt	Resident	Sea-run	Smelt	Eels	Killifish
1980	339	15028	73	796	814	35	1486	4
1981	199	15839	63	702	514	13	929	5
1982	375	12380	59	1293	0	19	439	0
1993	877	9986	90	731	0	43	162	0
1994	1345	10503	57	759	204	16	188	0
1995	152	12160*	43	33	503	13	7	0
1996	1111	12383	110	236	303	16	10	0
1997	196	6776	192	56	457	41	9	0
1998	133	5922	69	2	84	6	8	0
1999	295	9634	126	91	473	14	31	0

* The 1995 smolt count was adjusted to account for a washout that occurred during the latter part of the smolt run. The unadjusted count was 9009 smolts.

Smelt = *Osmerus mordax*
Killifish = *Fundulus diaphanus*

Table 7. Highlands River Atlantic salmon kelt tag release and recapture information, 1998 - 1999.

Release Information				Recapture Information			Area of Recapture				
Tagging Location	Year	Tag Type	Number Tagged	Total Number Recaptured	Year	Number	Highlands River	Humber River	Humber Estuary	Port au Port Sentinel Fishery	Quebec North Shore
Highlands River	1998	Archival	24	6	1998	6	4			1	1
		Carlin	32	6	1998	3	2				1
					1999	3	2		1		
	1999	Archival	29	7	1999	7	6	1			
		Carlin	37	4	1999	4	4				
Total			122	23		23	18	1	1	1	2

Table 8. Numbers of upstream migrating fish enumerated at the Highlands River fish counting fence.

Year	Numbers of fish migrating upstream				
	Atlantic salmon			Brook trout	
	Small	Large	% small	Resident	Sea-run
1980	82	55	59.9	0	10
1981	127	29	81.4	0	11
1982	100	56	64.1	0	15
1993	137	78	63.7	0	63
1994	145	148	49.5	74	208
1995	172	120	58.9	2	16
1996	199	142	58.4	0	10
1997	398	157	71.7	0	6
1998	96	117	45.1	0	0
1999	146	82	64.0	0	0

Table 9. Estimated survival of smolts in year i to small salmon in year i + 1, and to large salmon or 2SW salmon in year i + 2, at Highlands River, Newfoundland.

Year (i)	Number of Smolts (year i)	% survival to small salmon (year i + 1)	% survival to large salmon (year i + 2)	% survival to 2SW salmon (year i + 2)
1980	15028	0.85	0.37	0.31
1981	15839	0.63	-	-
1993	9986	1.45	1.20	0.93
1994	10503	1.64	1.35	0.81
1995	12160	1.64	1.29	0.70
1996	12383	3.21	0.94	0.52
1997	6776	1.42	1.21	0.46
1998	5922	2.47	-	-

Table 10. Values used in the determination of the level of conservation requirements met at Highlands River, Bay St. George, Newfoundland, based upon an egg requirement of 1.498 million eggs.

	Small salmon				Large salmon						
Year	Number	% female	No. of eggs per fish	No. of eggs	Number	% female	No. of eggs per fish	No. of eggs	Total No. of eggs small and large salmon	% contribution from large salmon	% conservation level achieved
1980	82	0.554	2890	131287	55	0.75	10151	418729	550016	76.1	36.7
1981	127	0.554	2890	203335	29	0.75	10151	220784	424119	52.1	28.3
1982	100	0.554	2890	160106	56	0.75	10151	426342	586448	72.7	39.1
1993	137	0.461	3088	195029	78	0.695	9175	497377	692406	71.8	46.2
1994	145	0.461	3088	206417	148	0.695	9175	943740	1150158	82.1	76.8
1995	172	0.461	3088	244854	120	0.695	9175	765195	1010049	75.8	67.4
1996	199	0.461	3088	283290	142	0.695	9175	905481	1188771	76.2	79.3
1997	398	0.461	3088	566580	157	0.695	9175	1001130	1567710	63.9	104.6
1998	96	0.461	3088	136663	117	0.695	9175	746065	882728	84.5	58.9
1999	146	0.461	3088	207841	82	0.695	9175	522883	730724	71.6	48.8

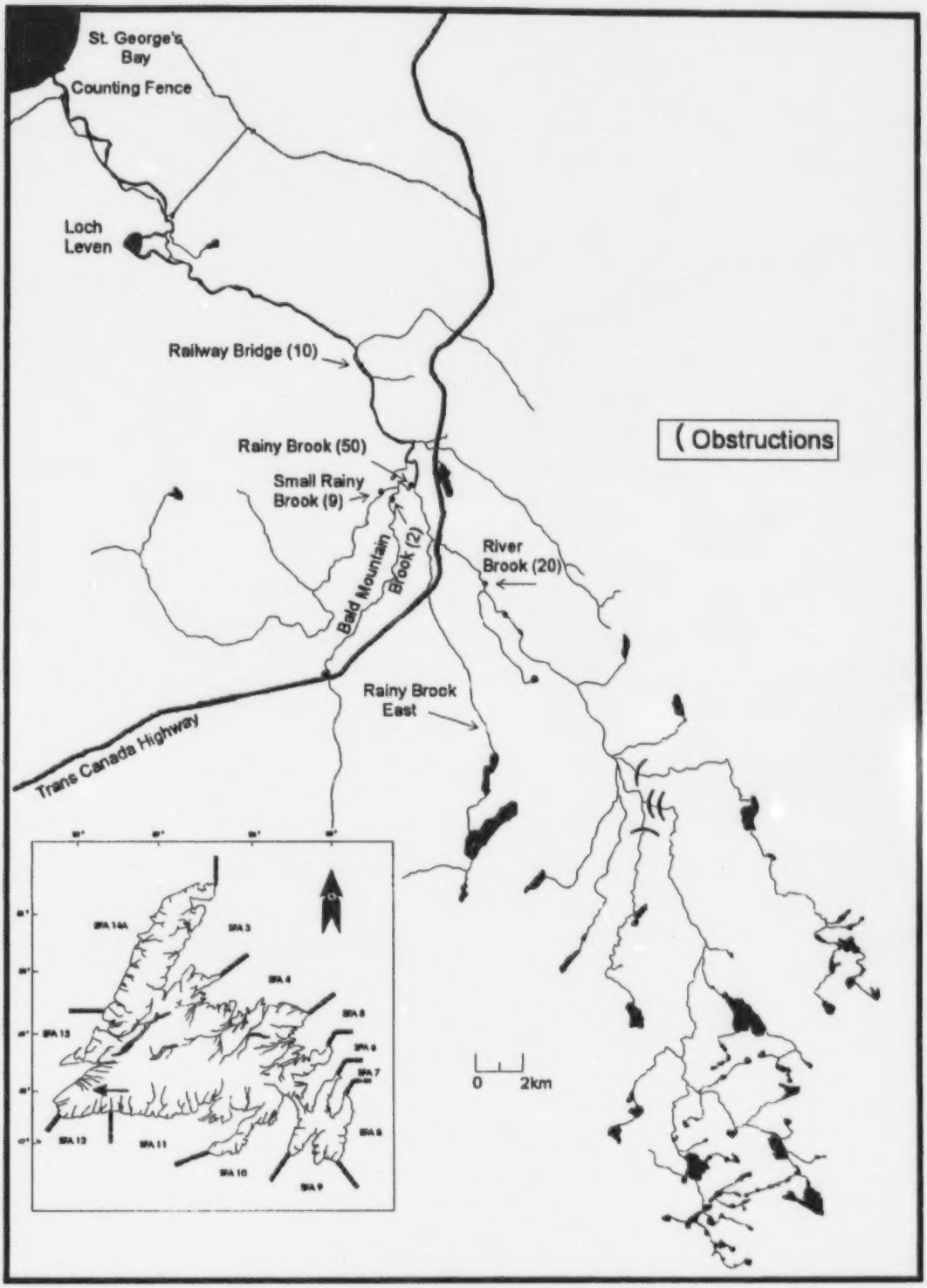

Fig. 1. Location of Highlands River, Samon Fishing Areas and electrofishing stations.

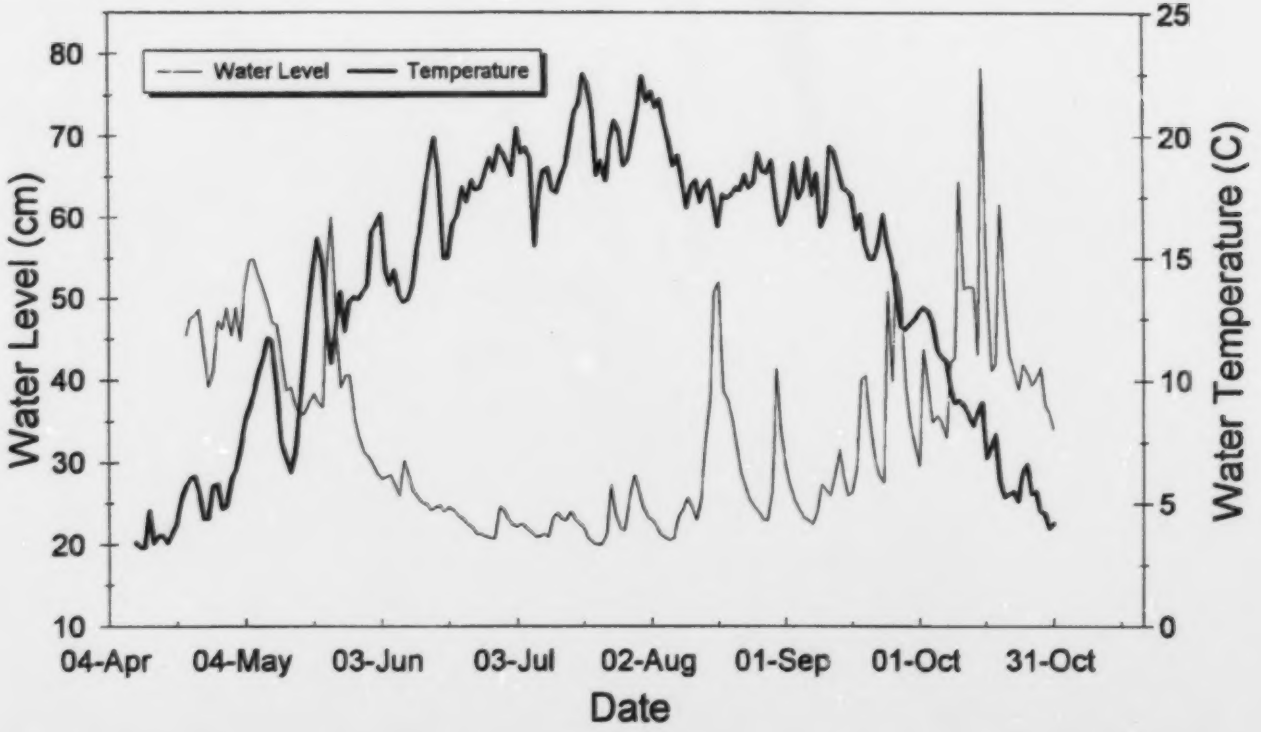

Fig. 2. Daily water level (cm) and water temperature (C) at Highlands River, SFA 13, 1999

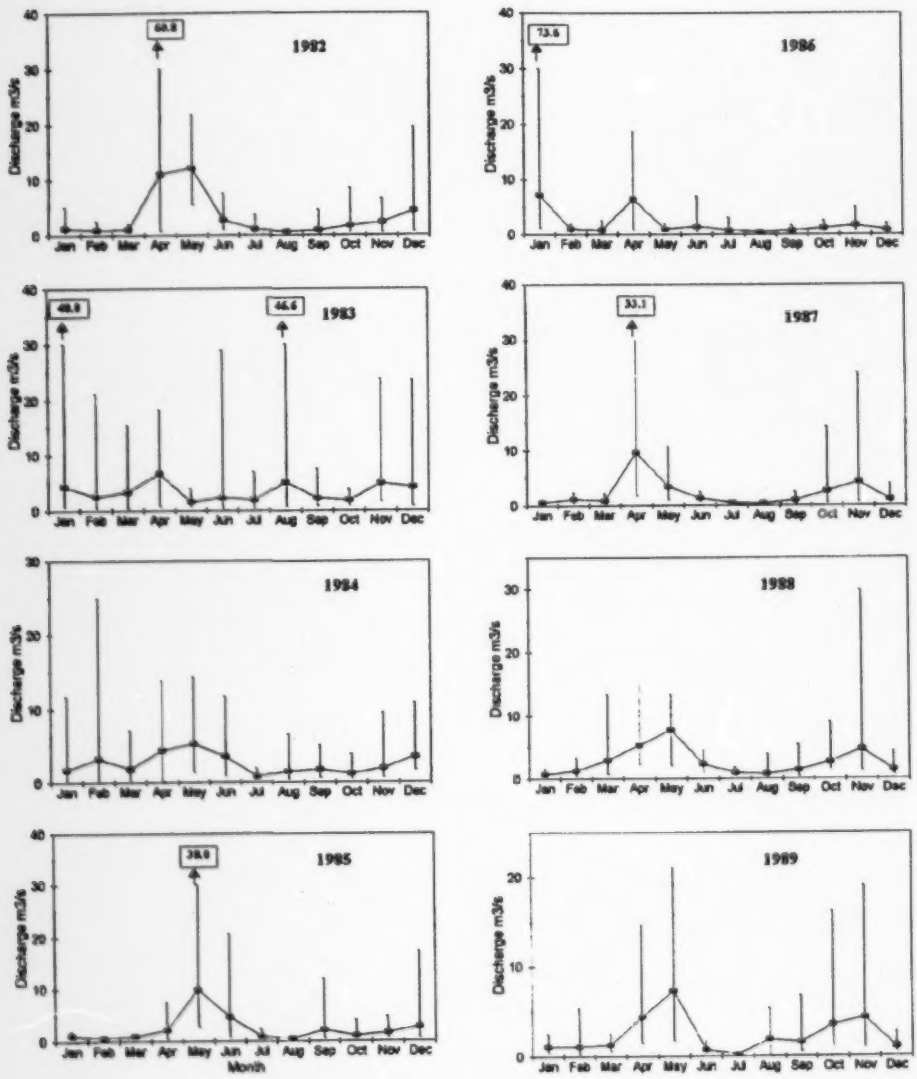

Fig. 3. Summary of maximum, minimum and mean daily discharge by month for Highlands River, Newfoundland, 1982 - 1989. Mean values are joined by a continuous line. Maximum values exceeding 30 m ^{3}/s are shown as a separate box for the respective months in which these high values occurred.

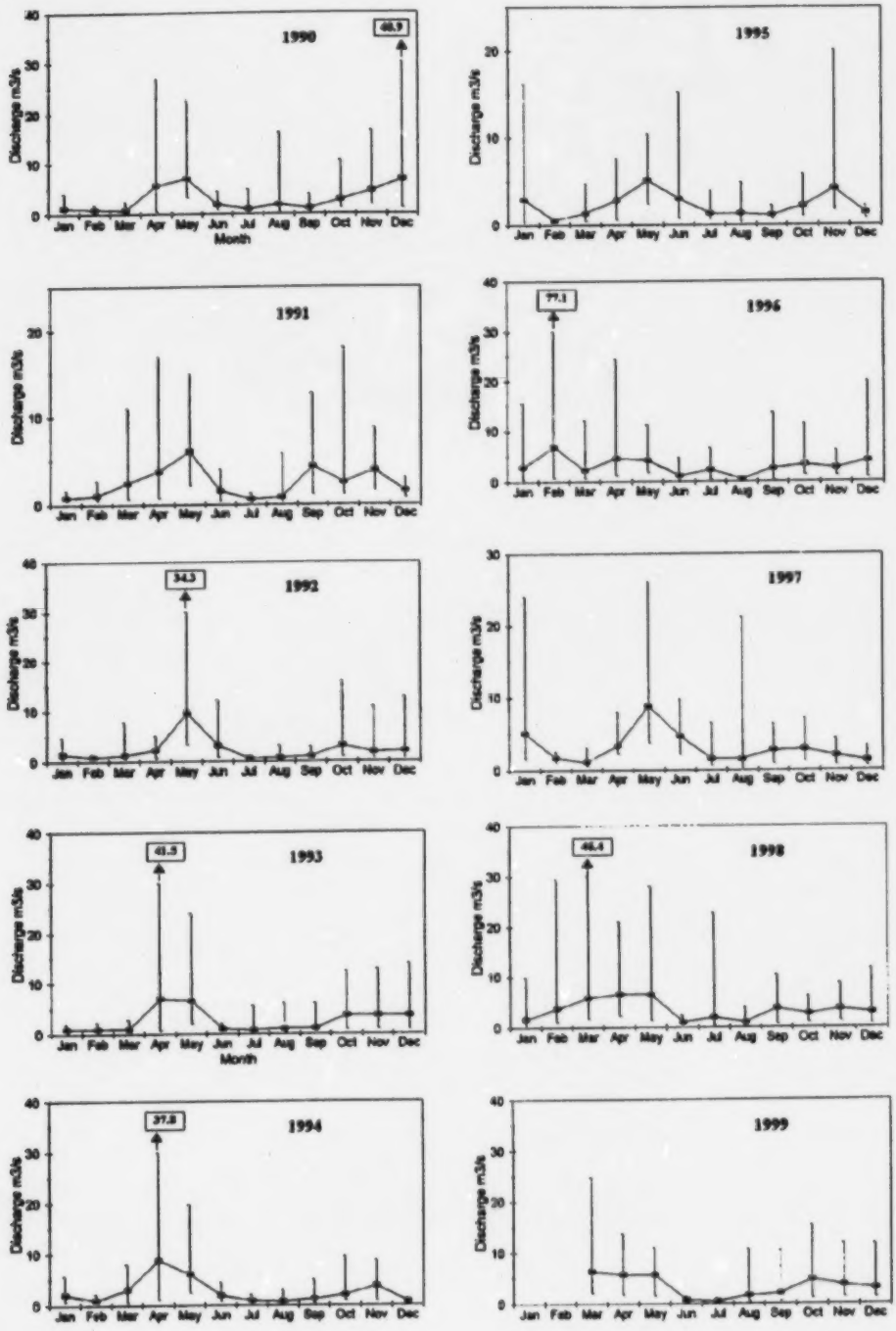

Fig. 3, continued. Summary of maximum, minimum and mean daily discharge by month for Highlands River, Newfoundland, 1990 - 1999. Mean values are joined by a continuous line. Maximum values exceeding 30 m^3/s are shown as a separate box for the respective months in which these high values occurred.
NOTE: Information for 1999 is PRELIMINARY.

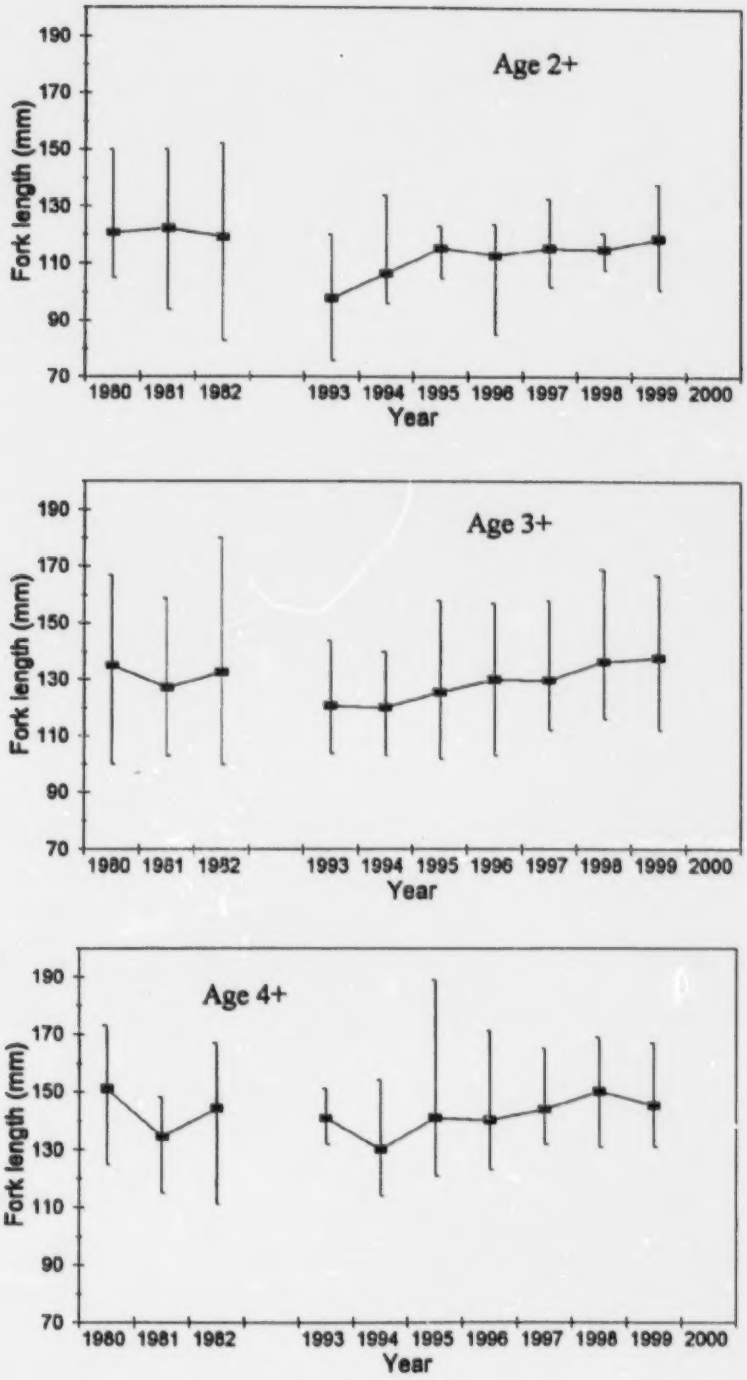

Fig. 4. Minimum, maximum, and mean fork length (mm) of river age 2+, 3+, and 4+ Highlands River smolt, from 1980 - 1982, and 1993 - 1999.

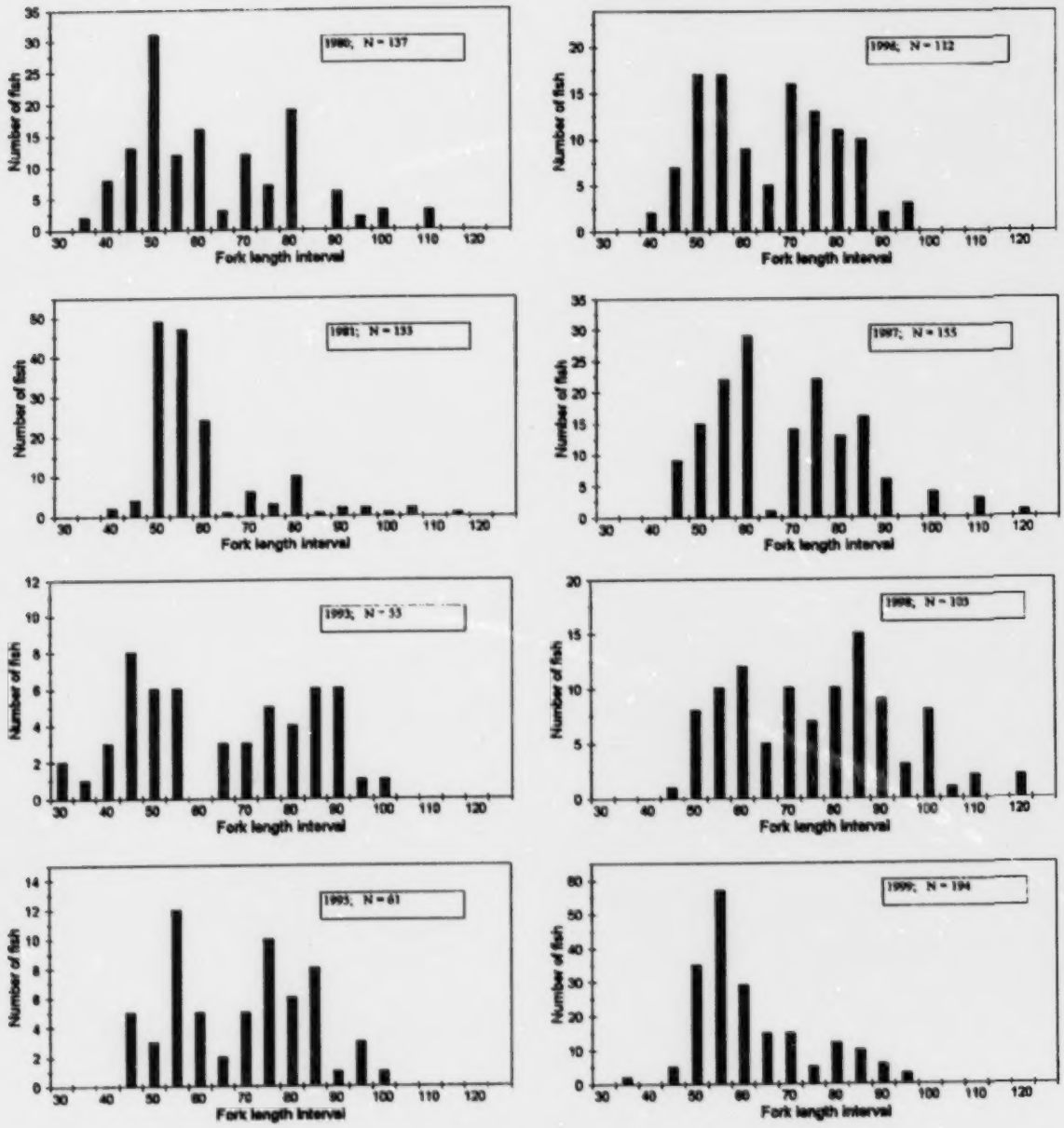

Fig. 5. Length distributions of adult Atlantic salmon estimated from fish in the fish counting fence trap at Highlands River, Newfoundland.

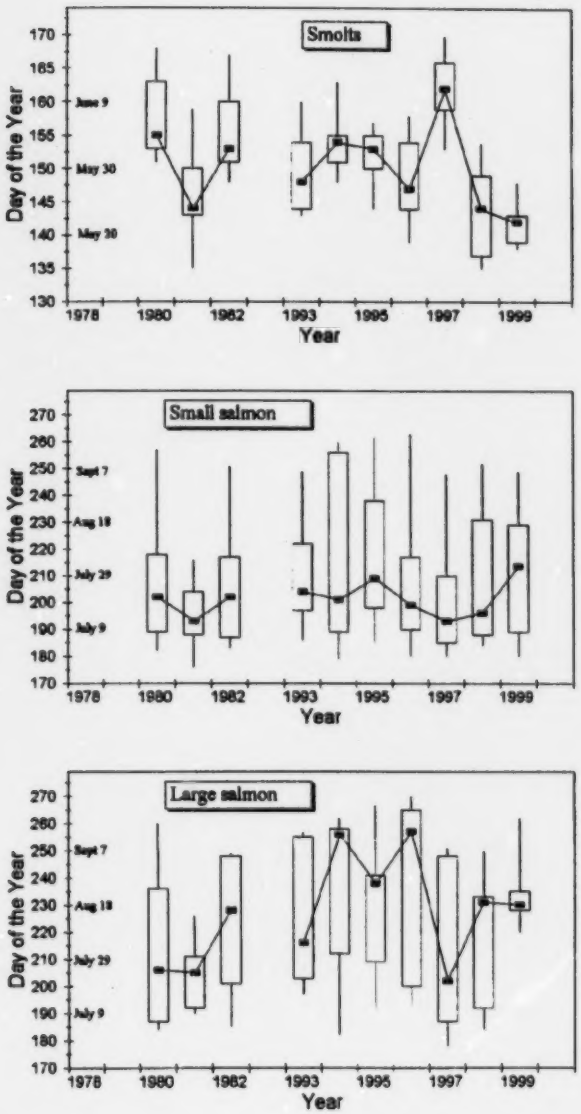

Fig. 6. Annual variation in run timing of Highlands River smolts, small and large salmon. Vertical lines represent the 10th and 90th percentiles of the day of the year of migration, the rectangle is the 25th and 75th percentiles, and the marker within the rectangle is the median run timing.

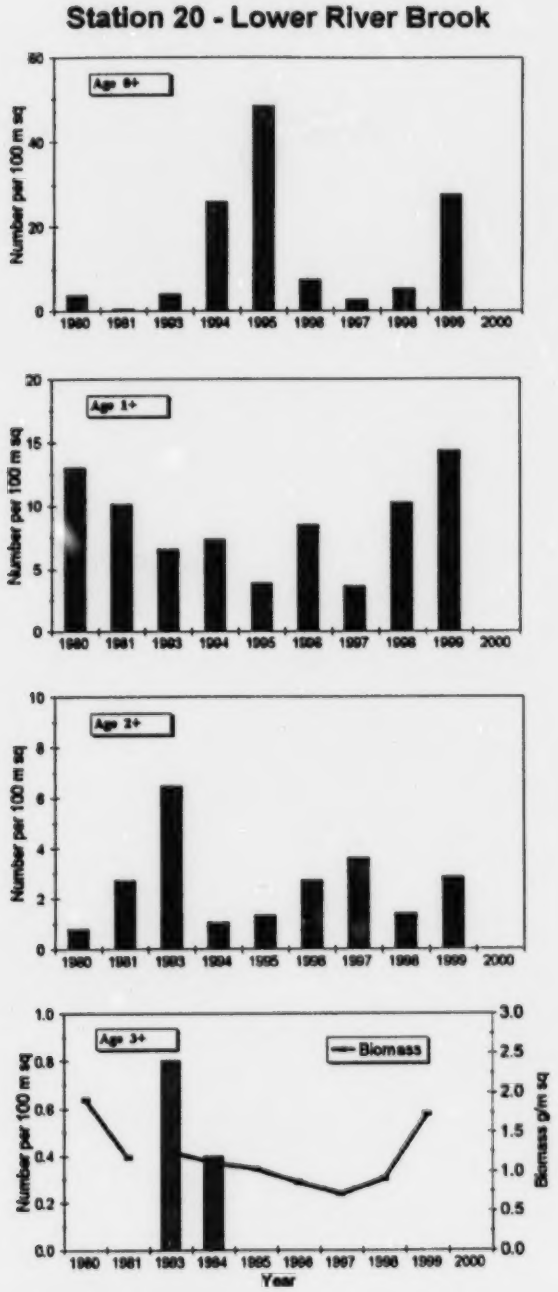

Fig. 7. Number of Atlantic salmon parr per 100 m square estimated by electrofishing at Station 20 (riffle habitat), lower River Brook, Highlands River. The bottom panel also illustrates the overall estimated population biomass (solid line) for all age groups combined.

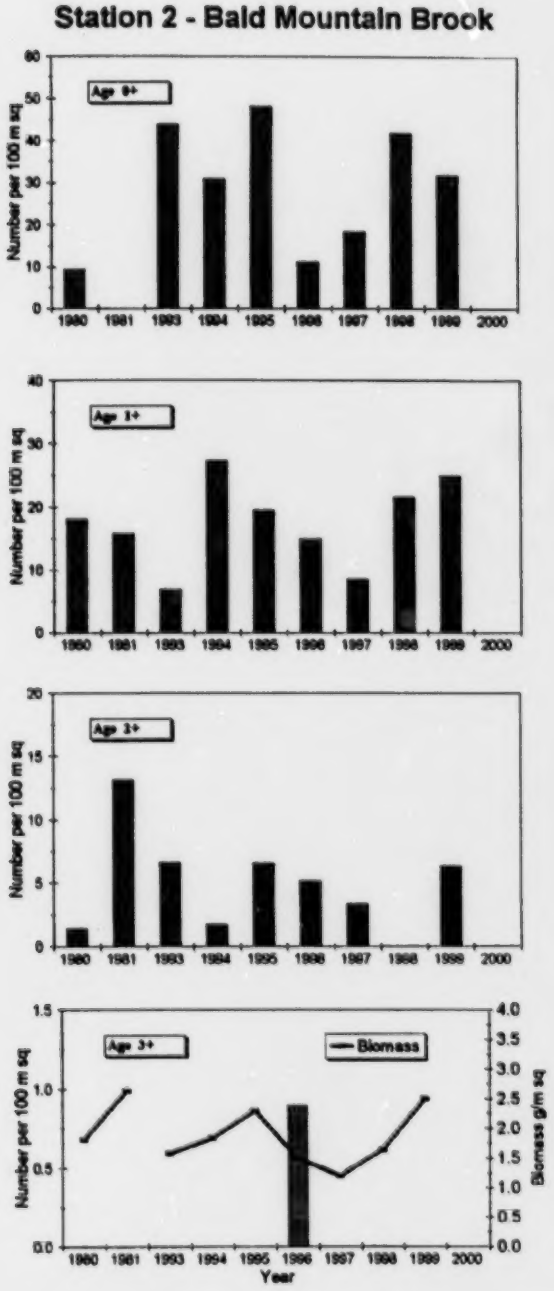

Fig. 8. Number of Atlantic salmon parr per 100 m square estimated by electrofishing at Station 2 (riffle habitat), Bald Mountain Brook, Highlands River. The bottom panel also illustrates the overall estimated population biomass (solid line) for all age groups combined.

Station 9 - Small Rainy Brook

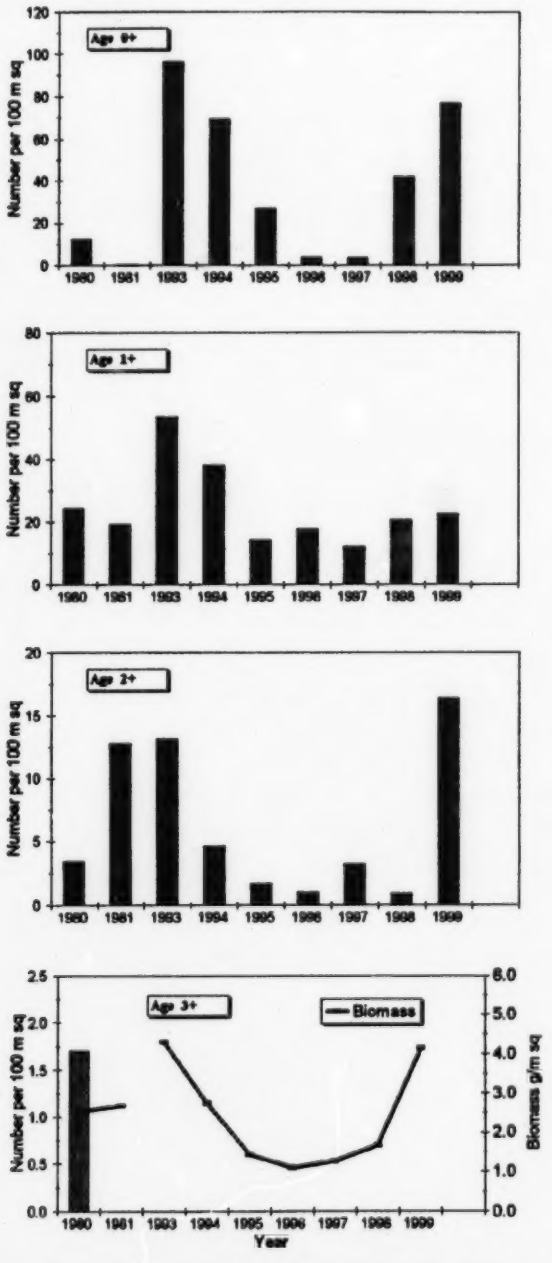

Fig. 9. Number of Atlantic salmon parr per 100 m square estimated by electrofishing at Station 9 (riffle habitat), Small Rainy Brook, Highlands River. The bottom panel also illustrates the overall estimated population biomass (solid line) for all age groups combined.

Station 10 - Railway Bridge Main River

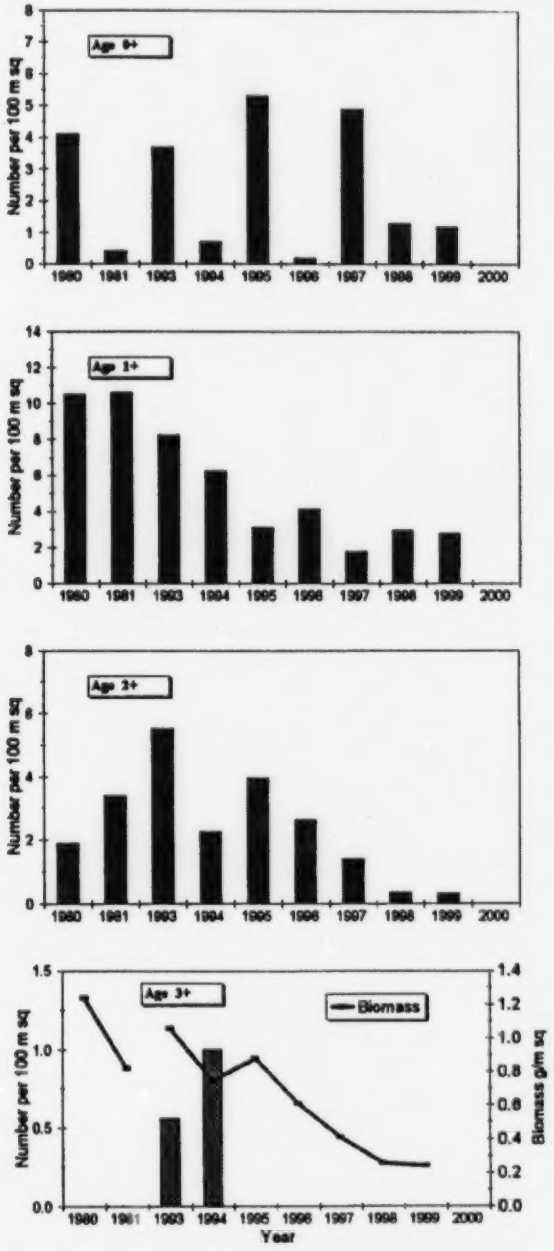

Fig. 10. Number of Atlantic salmon parr per 100 m square estimated by electrofishing at Station 10 (flat habitat), Railway Bridge, main stem Highlands River. The bottom panel also illustrates the overall estimated population biomass (solid line) for all age groups combined.

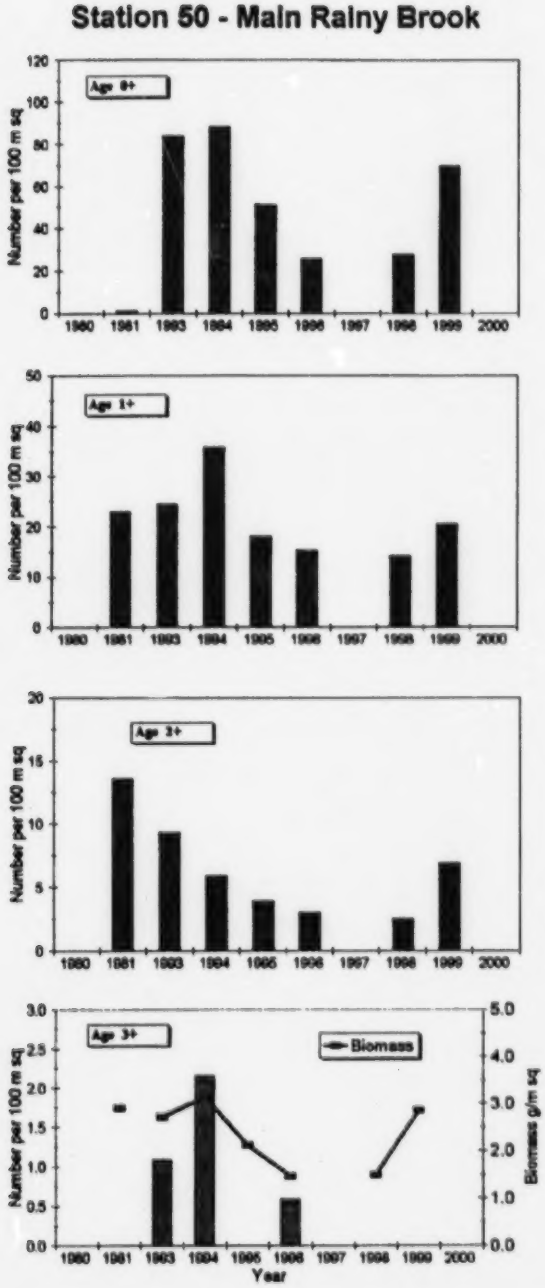

Fig. 11. Number of Atlantic salmon parr per 100 m square estimated by electrofishing at Station 50 (riffle habitat), main Rainy Brook, Highlands River. The bottom panel also illustrates the overall estimated population biomass (solid line) for all age groups combined.

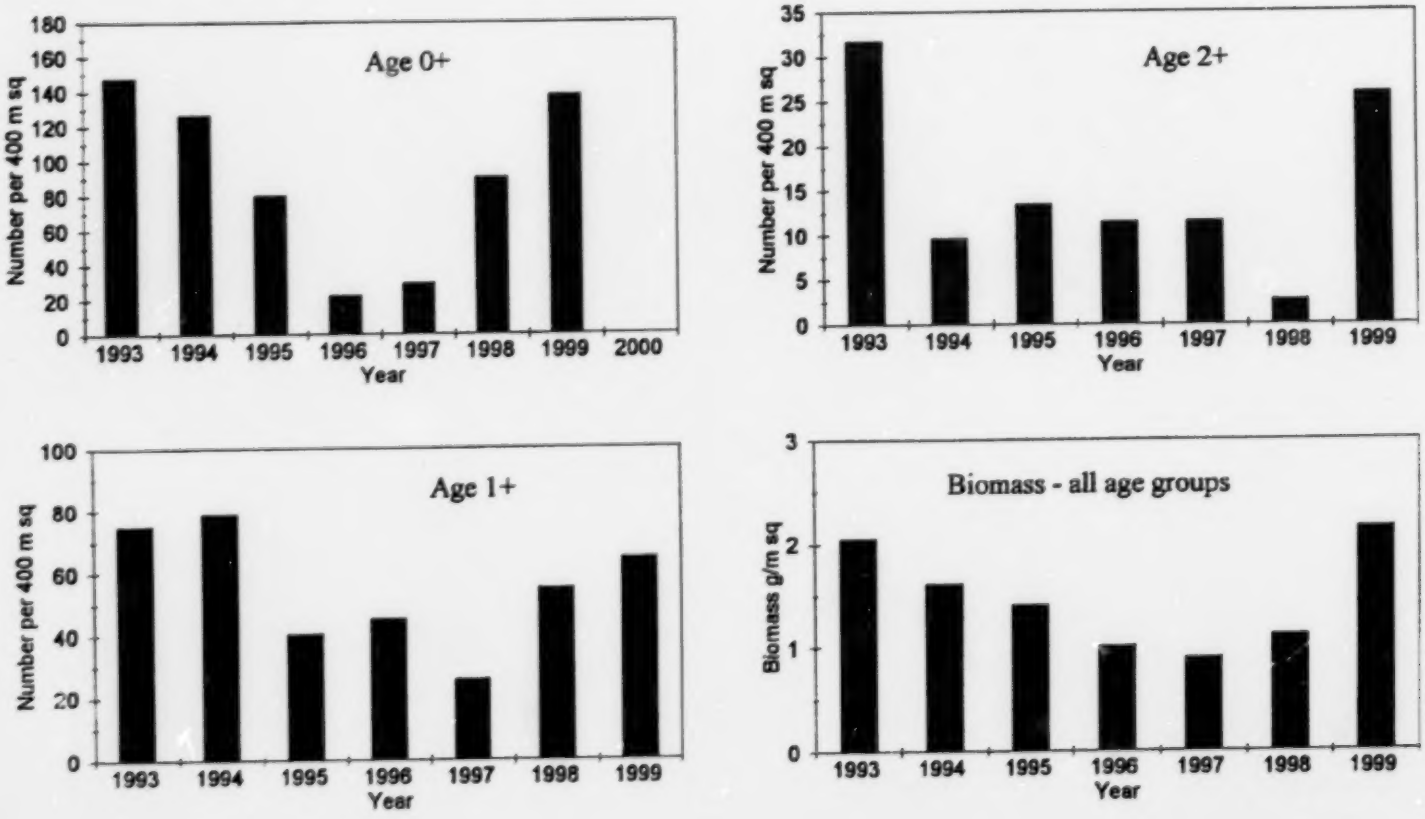

Fig. 12. Combined numbers of Atlantic salmon parr per 400 m square estimated from electrofishing at Stations 2, 9, 10 and 20, Highlands River, 1993 - 1999. The bottom right panel illustrates the combined population biomass for all age groups scaled to g per metre squared.

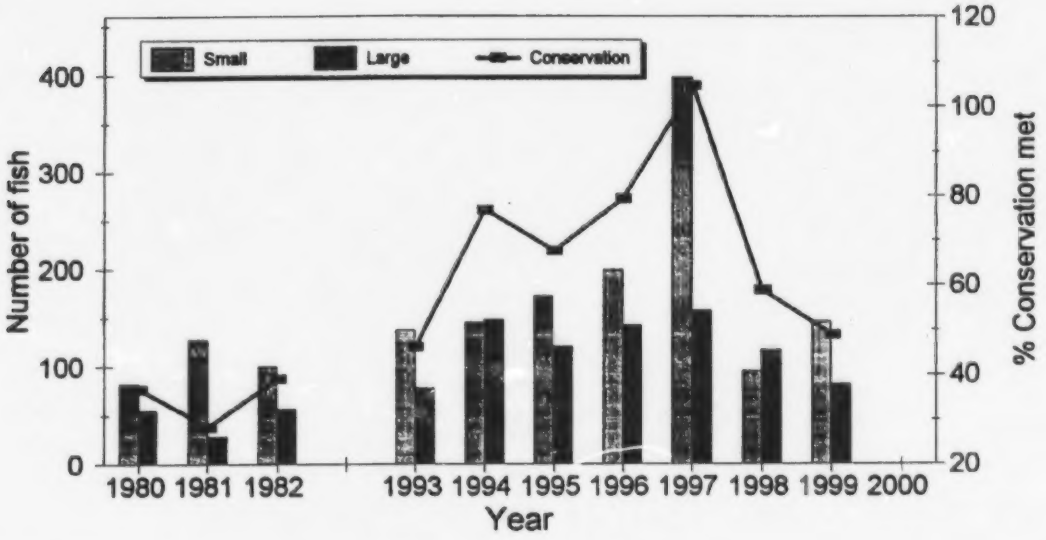

Fig. 13. Total numbers of small and large salmon returning to Highlands River, Newfoundland, along with the estimated percentage of the conservation requirement met.

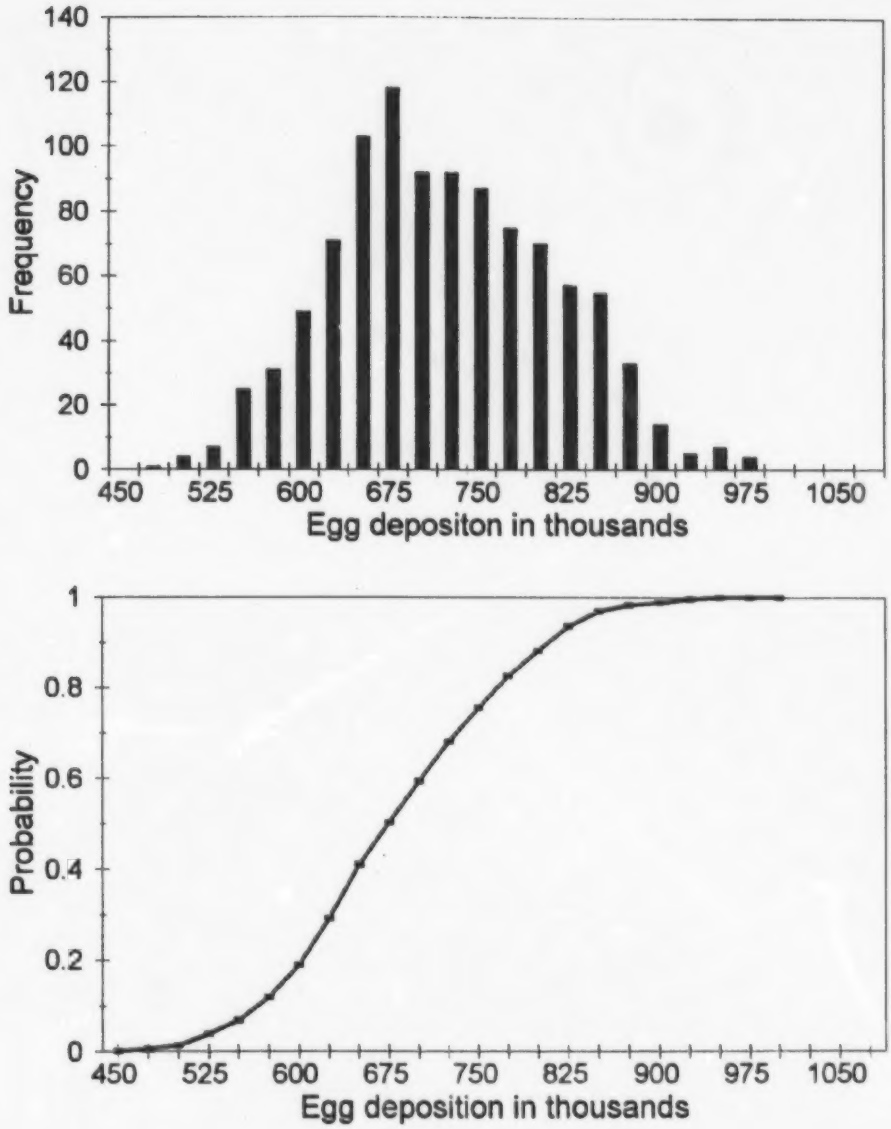

Fig. 14. Frequency distribution of the estimated egg depostion at Highlands River, 1999 (upper panel) and the corresponding probability distribution (lower panel). The analysis was done with 1000 realizations assuming a 20% coefficient of variation around both the fecundity and percentage females of the small and large salmon components. Egg depositions are in thousands showing the lower bounds of each interval.

Appendix 1. Summary of the raw numbers of juvenile Atlantic salmon parr caught during repeated electrofishing surveys at Highlands River, Newfoundland, 1980 - 81 and 1993 - 1999.

Station 2: Bald Mountain Brook

Sweep	1980	1981	1993	1994	1995	1996	1997	1998	1999
1	65	49	25	37	43	26	16	40	40
2	51	19	18	15	18	12	6	29	16
3	22	11	12	12	12	5	13	11	11
4	25	7	5	2	4	0	2	9	2
5	-	-	-	-	-	-	3	-	-
Total	163	86	60	66	77	43	40	89	69

Station 9: Small Rainy Brook

Sweep	1980	1981	1993	1994	1995	1996	1997	1998	1999
1	127	50	98	122	56	30	25	68	97
2	96	21	56	70	17	16	19	44	57
3	59	11	48	40	15	10	7	28	45
4	41	14	40	23	6	5	2	21	29
Total	323	96	242	255	94	61	53	161	228

Station 10: Railway Bridge Main River

Sweep	1980	1981	1993	1994	1995	1996	1997	1998	1999
1	193	56	50	32	50	20	22	16	5
2	74	30	30	8	13	7	10	9	2
3	90	61	6	4	5	5	11	0	4
4	0	0	6	7	3	4	2	-	2
5	-	-	10	1	-	-	-	-	1
Total	357	147	102	53	71	36	45	25	14

Station 20: Lower River Brook

Sweep	1980	1981	1993	1994	1995	1996	1997	1998	1999
1	56	83	36	53	131	24	11	45	25
2	48	36	30	40	63	27	10	13	36
3	60	35	20	25	30	15	2	10	40
4	52	14	7	12	15	3	2	3	22
5	-	-	6	-	-	-	-	-	13
6	-	-	-	-	-	-	-	-	19
7	-	-	-	-	-	-	-	-	10
Total	216	168	101	130	239	69	25	71	165

Station 60: Main Rainy Brook

Sweep	1980	1981	1993	1994	1995	1996	1997	1998	1999
1	-	-	68	110	44	30	-	42	83
2	-	-	66	56	22	19	-	31	54
3	-	-	26	29	14	8	-	25	41
4	-	-	16	22	9	6	-	23	26
Total	-	-	176	217	89	63	-	121	204

STOCK: **Highlands River (SFA 13)** **Drainage area:** 183 km²

CONSERVATION REQUIREMENT: 1.5 million eggs calculated as fluvial area x 2.4 eggs/m² and lacustrine area x 368 eggs/ha

Year	1994	1995	1996	1997	1998	1999 [2]	MIN [1]	MAX [1]
Total returns to home waters								
Small	145	172	199	398	96	146	82	398
Large	148	120	142	157	117	82	29	157
Recreational harvest (small salmon)								
Retained	—— Closed to angling since 1978 ————							
Released								
Recreational harvest (large salmon)	—— Closed to angling since 1978 ————							
Retained								
Released								
Spawners								
Small	145	172	199	398	96	146	82	398
Large	148	120	142	157	117	82	29	157
Conservation requirement								
% met	77	67	79	105	59	49	28	105
Smolt count	10503	12160	12383	6776	5922	9634	5922	15839
% Sea survival								
Small	1.5	1.6	1.6	3.2	1.4	2.5	0.6	3.2
Large (Adult return year)	-	1.2	1.4	1.3	0.9	1.2	0.4	1.4

[1] Min and max are for the period of record since 1974.
[2] Preliminary

Data and methodology: Counts of smolt and adult salmon were obtained with a fish counting fence in 1980 - 82 and in 1993 - 99. Juvenile salmon densities were measured at 5 stations in 1999 to determine changes in juvenile salmon production. Sea survival is calculated for small salmon returning in year i + 1 and for large salmon returning in year i + 2, by dividing the number of returning adults by the number of smolts in year i.

State of the stock: The number of large salmon returning has increased since the closure of the commercial salmon fishery in 1992, but has fallen in each of the past two years since the peak in 1997. Small salmon returns are variable. The conservation spawning requirement was achieved in only one year (1997) and fell to below 50% of the requirement in 1999.

Forecast: The conservation spawning requirement will likely not be met in 2000 unless there is a corresponding increase in marine survival rates. Based upon the average egg deposition contribution from small and large salmon, respectively, over the past 7 years (1993 - 1999), marine survival rates approximating 2.7% for small salmon returns from the 1999 smolt class and 3.0% survival for large salmon returns from the 1998 smolt class would be required. To date, the highest survival to large salmon has been only 1.35%.